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Industrial Training, An Experimental Study of the Use of Sound
Films in the Training of Engine
Lathe Operators

A PART OF A DISSERTATION SUBMITTED TO THE FACULTY
OF THE DIVISION OF THE SOCIAL SCIENCES IN CANDIDACY
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF EDUCATION

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THE ECONOMY OF TIME IN INDUSTRIAL TRAINING

AN EXPERIMENTAL STUDY OF THE USE OF SOUND FILMS IN THE TRAINING OF ENGINE LATHE OPERATORS

A. W. VANDER MEER

Lt.(jg) U.S.N.R.

A number of experimental studies have shown that sound motion pictures are effective tools for teaching factual information, promoting inductive reasoning, and developing attitudes. How useful are films in predominately motor learning situations? Is the tremendous popularity of training films in the Armed Forces and in industry justifiable on scientific grounds? In order to provide a partial answer to the foregoing questions, the author developed a technique for using sound films in the training of engine lathe operators; then conducted a controlled experiment to determine whether such a technique could result in a saving of time in the teaching of twelve lathe skills.

The choice of engine lathe trainees was conditioned by three factors: (a) the problems involved in training this type of worker were considered to be fairly representative of those involved in training a large class of machine operators, (b) it was possible to work with larger groups of lathe trainees than trainees on any other machine, and (c) U. S. Office of Education training films were available on most lathe operations.

The Hypotheses Tested.—The main (null) hypothesis tested was that prospective engine lathe operators whose instruction includes the carefully integrated use of training motion pictures do not develop the essential skills to the required level in a shorter time than those whose training does not include such visual aids. A second hypothesis was that the trainees whose instruction

includes motion pictures do not learn more technical information related to machine operation than do trainees whose instruction does not include such experience.

Definition of Terms.—Two terms should be defined in the interests of clarity. As used in this research, the term 'integrated film use' excludes the type of film use involved in time and motion studies. Instead of being based on an analysis of errors, films used in this research were intended to provide the best possible model of the skills to be learned. Furthermore, as will be indicated later, the term integrated as applied to film utilization implies that motion pictures are used as an integral part of the teaching process.

A second term that should be defined is the 'development of skills to the required level.' It is always difficult to draw a definite line distinguishing those who have learned the skill from those who have not. When the application of the skill results in a product which may be accurately and objectively measured, however, the extent to which an individual has learned that skill may be stated in terms of the quality of the product and the length of time required to produce it. Quality can be held constant when the product is of such a nature that it can logically be either accepted or rejected without reference to any intermediate quality between acceptance and rejection; then the measure of an individual's skill is the length of time he requires to turn out an acceptable product.

The development of skills on the engine lathe may be determined in the manner described in the foregoing paragraph, for when a lathe hand is given a blueprint and a piece of stock he is expected to turn out a job that meets certain definite specifications within prescribed tolerances. Variations within the tolerances make no difference in the quality of the work. As long as the specifications are met, the only criterion of the worker's skill is the amount of time he takes on the job.

For the purposes of the present research, a skill is said to have been learned when an individual has applied it independently in turning out an acceptable piece of work requiring the application of the skill. Since in actual machine shop practice the amount of stock that a worker spoils by cutting off too much metal is also a criterion of his skill, data on the number of under-size pieces turned out by each group will also be compared.

Previous Studies.—Although motion pictures have been widely used in instruction in motor skills, relatively few controlled experiments have been conducted on this subject. Freeman, Shaw and Walker¹ found that penmanship classes taught with motion pictures improved more in 'writing position' than did classes taught with a variety of other methods. No significant differences in quality of handwriting resulted, however. Hollis,² McClusky,³ and Rolfe⁴ have experimented with the use of silent motion pictures in the teaching of home economics, handicrafts, and physics laboratory work. Their findings agree that the demonstration is superior to the unaided film in teaching representative skills in these school subjects.

Priebe and Burton⁵ paired twenty-six adolescent boys in terms of age, height, weight, leg spring, previous athletic experience, and natural jumping ability. The conclusions were that the use of films in teaching high jumps resulted in greater improvement and shortened the initial period of trial-and-error learning.

The Curriculum Setting of the Experiment.—The experiment was conducted within the framework of a regular machine operator's training program. The course was given in the Morton High School (Cicero, Illinois) shops for new employees of the Amertorp Naval Ordnance Plant. The training period was divided into six forty-hour weeks. Classes met eight hours per day from 10:30 P.M. to 7:00 A.M. Monday through Friday.

The general objectives of the training course were as follows:

- 1) The development of specific skills in lathe operation.
- 2) The acquisition of basic information relating to machine operation.
- 3) The development of skill in blueprint reading and shop mathematics sufficient to carry on effectively in a factory situation.
- 4) The development of habits and attitudes conducive to safe and efficient machine operation.

¹ *Visual Education, A Comparative Study of Motion Pictures and Other Methods of Instruction.* Frank N. Freeman, Editor. p. 309. Chicago: The University of Chicago Press, 1924.

² *Ibid.* pp. 339-41.

³ *Ibid.* pp. 310-34.

⁴ *Ibid.* pp. 335-38.

⁵ Priebe, Roy and Burton, William H. "The Slow Motion Picture as a Coaching Device," *School Review*, XLVII (March, 1939).

There was one instructor in charge of each of three machine shops. All three instructors were craftsmen. None had had previous training in the theory or methods of teaching. The instructors in the beginners' and advanced shops had been teaching for approximately six months at the start of the experiment. The instructor in the intermediate room had been teaching for only one month.

The trainees were sent to the training center in groups of approximately fourteen. Each group spent an equal amount of time under the guidance of each instructor; two weeks each in the beginner's shop, the intermediate shop, and the advanced shop. Up-grading experiences designed to help the students to progress toward the four general objectives were provided in each room. The lathe skills required became more difficult as the student progressed, and the tolerances allowed on jobs became smaller.

The following outline indicates something of the division of subject-matter among the three rooms:

1. Beginner's Shop.

- a. General care and operation of the lathe.
- b. Uses and care of small tools.
- c. Lathe tool grinding.
- d. Reading the micrometer and steel rule.
- e. Truing, facing and centering work held in a chuck.
- f. Aligning lathe centers.
- g. Rough turning between centers.
- h. Turning work of two and five diameters.
- i. Blueprint reading.
- j. Shop mathematics.
- k. Shop safety.

2. Intermediate Shop.

- a. Turning work to five diameters.
- b. Turning a taper with tailstock set over.
- c. Turning a taper with the taper attachment.
- d. National fine threading.
- e. Turning a taper with the compound rest.
- f. Knurling.
- g. Blueprint reading.
- h. Shop mathematics.
- i. Shop safety.

3. Advanced Shop.

- a. Use of the dial indicator and steady rest.
- b. Left-hand and right-hand coarse threading.
- c. Three wire method of thread measurement.
- d. Advanced care and operation of the lathe.
- e. Shop safety.
- f. Drilling and boring work held in a chuck.
- g. Theory and operation of milling machine, surface grinder, and drill press.
- h. Shop mathematics.
- i. Blueprint reading.

The equipment was adequate. While the lathes in the beginner's room were noticeably inferior to those in the intermediate and advanced rooms, this fact could not affect the relative standings of the groups since all groups used the same equipment. There were slight differences in quality of machines within rooms. This was compensated for by rotating the students' assignments to lathes.

The Groups Used in the Experiment.—The groups used were seven consecutive classes of engine lathe trainees from the Amertorp Naval Ordnance Plant. No special selection was applied to determine which employees would come to the Morton Training Center where the experiment was being carried on. Each of the first six groups was selected in its entirety as either experimental (film) group or as a control (non-film) group. In order to equalize the advantage of better teaching on the part of the instructors as the experiment went on the first, fourth and fifth groups were chosen as controls and the second, third and sixth groups were chosen as experimental groups. The seventh group was the only one in which the trainees were divided between the experimental and control groups.

The size of the groups ranged from eleven to seventeen. It would probably be safe to say that the people who served as subjects for this experiment were fairly typical of the thousands who were hired for training and work in war plants all over the country. The age of the trainees ranged from eighteen to fifty-five years with a median of thirty. About one-third of them had had four years of high school, most often in a general or commercial course. Women outnumbered men by three to one.

Both experimental and control groups were told frankly that they were being used as subjects of an experiment and were asked for their coöperation. The false impression of lack of importance frequently given to control groups in similar experimental situations was scrupulously avoided. On the contrary, the importance of their part in the experiment was strongly impressed upon all groups, and there was every evidence in the actions of the trainees that they realized the value of such an experiment. Furthermore, the spirit of competition among groups was avoided. While the members of various groups knew in a general way the significance of the time scores which they were keeping, they had little opportunity to compare group averages on any of the criterion measures.

The Treatment of the Groups.—The essential difference in the treatment of the control and experimental groups was in methods and materials of instruction. All groups, with the exception of a few individuals, completed a six weeks' training course on the engine lathe. The same instructors taught all groups, all groups worked in the same shops with the same equipment and on the same lathe projects. All were given the same general basic background information in one way or another. However, with one set of groups, the experimental or film groups, a battery of U. S. Office of Education training films was used as an integral part of the instruction. The other set of groups, the control or non-film groups, viewed no films, but rather were taught with the conventional lecture-demonstration method. The experimental groups did not forego demonstrations entirely, but the use of films usually made it unnecessary for their demonstrations to be so long or so numerous as those of the control groups. The instructors gave a considerable amount of individual attention to the members of both groups, and in every respect except the film teaching the groups were taught in a similar manner.

The Required Lathe Jobs.—Each trainee in each group was required to finish twelve projects which were designed to develop skill in what were considered essential engine lathe operations. The major comparisons between the groups were based upon the average time spent by the trainees per successful trial on each job. On all but two of the jobs two or more trials were required. Such trials were accomplished by turning the same piece of stock down to successively smaller dimensions. It might appear, on

the surface, that under such conditions a trainee might reduce his time score by being, for example, .050 inch under size on his first trial. This would leave him only .013 inch of stock to remove for his second trial. However, the method of computing the average time per successful trial was specifically designed to prevent such a procedure from working to the advantage of the trainee. The time is figured cumulatively; therefore, the lengthened time on the first trial would not in the end be subtracted from any important score, but would in reality be added to his total average. This distinction will be explained more fully in the section on keeping the time record.

The required lathe jobs are listed and described in Table 1, which also indicates which films were used in the instruction of the film groups. It should be pointed out that single films frequently demonstrated the skills involved in several jobs. In such cases, a single film lesson was all that was employed.

All the films used were produced under the supervision of the U.S. Office of Education. Their contents have been described in a number of periodicals such as *Business Screen*, and need not be repeated here.

The Comparisons Based on Time Scores. Keeping the Time Records.—The major comparisons between the two groups, as previously pointed out, were made in terms of the average time they required to finish each of the twelve lathe projects to the tolerances allowed. Of critical importance to the experiment, therefore, was the method of recording and computing the time spent by each trainee on each job. Two time records were kept. On each trainee's drawings of his required projects was a form for keeping his time record. There were blanks in which to enter to the nearest five minutes the time when work was started and finished. Time taken from the job for tool sharpening, breakdown of lathes, interruptions for lectures, and so on, was also recorded. Instructors kept careful check to see that trainees 'kept their time' faithfully. Checking of the time record was made a part of checking on the acceptability of each trial of each job.

A second time record was kept as a partial check on the individual records kept by the students. Each class had a group time sheet for every day of the training period. On this sheet each trainee entered his beginning time and ending time not only

for his various jobs and trials, but also for all the other activities. One student in each group was placed in charge of this record sheet and helped the instructor to see to it that time records were accurately and faithfully kept.

TABLE 1.—LATHE JOBS AND TRAINING FILMS

					Trials	
Job	Skill	Tolerances		Critical	Al-	Film
1-L	Straight turning	(# inches)		Dimensions	lowed	
		.001	.063	Reductions	4	Rough turning between centers
				.050 inch		
2-L	Work of two diameters	.001	.063	Reductions	2	Turning work of two diameters
				.125 inch		
3-L	Work of five diameters	.001	.063	Reductions	4	"
				.063		
1-H	"	.0005	.063	Reductions	4	"
				.063		
4-H	Taper turning	.0005	.063	Tapers	3	Turning a taper with the tail-stock set over
				.300		
				.475		
				.600		
5-H	Fine thread- ing	Nut test	.063	National fine #11, 13, 16	3	Cutting a national fine thread
6-H	Taper turning	.0005	.063	.600 Morse	1	Turning a taper with the taper attachment and with the compound rest
7-H	Taper turning	1 degree	.063	30° internal 45° external	1	
1-V	Truing in chuck			.002 excentric	1	Height gages and indicators
2-V	Coarse threading	.0005		No. 6	2	Cutting external acme thread
3-V	Drilling and boring	.0005		Increases .050 inch	5	Drilling, boring and reaming work held in chuck

The experimenter maintained closest touch with every group and made it a practice to check the time records at least every other day. Inconsistencies and failures to enter time records were rare. Those that did occur were usually confined to the trainee's first few days of work. Consequently, the investigator has a great deal of confidence in the accuracy of the time records.

Computing the Time Scores.—In stating the original hypothesis it was pointed out that lathe projects lend themselves admirably to an absolute system of acceptance or rejection. For example, a trainee may be asked to turn a steel rod down to one inch in diameter. He is told that his tolerance is .001 inch. It will make no difference in the quality of his work how close his finished piece is to one inch as long as it is no farther off than .001 inch. A piece measuring .999 inch is just as good as a piece measuring 1.000 inch. By the same token, a piece measuring .998 inch cannot be counted ninety-nine per cent correct, for it is probably worthless for the purpose for which it was made.

It is, therefore, logical to compute the individual's time score in terms of how much time he required to turn out his job to specifications regardless of how many pieces he has ruined before getting it right. Since several jobs required several trials it was possible for an individual to turn out more than one acceptable specimen of a given job. In such cases the time for the several trials was averaged. Here is a sample record of an individual completing Job 1-L, which required four trials:

First trial	—100 minutes—accepted
Second trial	— 75 minutes—rejected
Third trial	— 70 minutes—accepted
Fourth trial	— 70 minutes—accepted

His time score for the job would be the total time, 315 minutes, divided by the number of successful trials, (three), or 105 minutes per successful trial. It will be seen that the time score is the average number of minutes spent by the individual per successful trial on any given job. The time on which the average is based is the cumulative total time spent, regardless of how many trials meet the rigidly defined and objectively measured specifications.

Informational Gain.—In addition to the records of average time per successful trial on each of the twelve jobs required in the course of the training program, it was the intention of the investigator to collect data bearing on the gains in factual information made by the trainees. Accordingly the Purdue Test for Machinists and Machine Operators was given to all groups on entering and again on leaving the training program. Informational gains were computed by subtracting the entering test score from the leaving test score. The same form of the test was used both as

pre-test and post-test. Such a procedure is partially justified by the fact that the test is an hour long and is made up of one hundred thirty-three items nearly all of which were unfamiliar to the entering trainee. The instructors were given no opportunity to familiarize themselves with the test, so that even had they been biased in favor of one or the other of the groups they could not have given special instructions to any group.

Factors Considered in Equating Groups.—The factors finally considered in equating groups were selected from a variety of information gathered at the beginning of the experiment. Records of the routine employment interview were examined to determine the age, work experience, education, hobbies and sex of each trainee. Experience and hobbies were classified as mechanical or non-mechanical. Mechanical hobbies were listed by 6.8 per cent of the control and 10.6 per cent of the experimental group. Of the control group 31.8 per cent claimed previous occupations classed as mechanical as compared with 34 per cent of the experimental group who claimed such previous occupations as assembly work, automatic machine operation, carpentry, and so on.

The first task of each entering group of trainees was to take a battery of tests which were intended for use in further equating of groups. The group tests given included: (1) the Purdue Industrial Training Classification Test, (2) Minnesota Paper Form Board, (3) The Wonderlic Personnel Test, and (4) the Purdue Test for Machinists and Machine Operators. Before administering the tests the investigator described the purpose and importance of the experiment, and explained the relation of the tests to the study. This preliminary talk and the order of presentation of the tests were identical for all groups. The whole testing time was approximately two and one-half hours including a ten-minute recess between taking Classification and Minnesota tests which were administered first, and the Personnel and Machinist's tests which were administered last. Each test was checked by two independent scorers, and discrepancies in score that occurred were reconciled.

Motor ability was measured by an individual test administered within the trainee's first two days in the course. Identical directions were given each trainee taking the test. Since it was a performance test, care was taken to exclude onlookers. This

precaution protected the test subject's peace of mind and minimized the possibilities of some trainees 'learning' the test before taking it.

The apparatus required for the test was designed by the investigator, but the original idea for the type of test may be credited to Hull.¹ A mechanical pencil was held vertically by a steel rod bolted into the tool post on the compound rest of an engine lathe. A drawing board was bolted in position on the ways of the lathe. By turning the two wheels on the compound rest it was possible to make the pencil follow around a two-inch circle tacked on the drawing board. The student was instructed to "make the pencil follow around the circle in the shortest possible time without getting any farther from the circle than necessary," and the manner of turning the wheels so that the pencil would follow the circle was demonstrated.

Elimination of Certain Factors in Equation.--At the close of the experiment, trainees' ages, years of education and scores on the tests of perception, mathematics, motor ability, and technical information were correlated with an over-all criterion of speed and accuracy in lathe operation which was derived from the time scores on the twelve jobs. The correlation coefficients are shown in Table 2. Although only two of the correlations are positive in terms of the sign which precedes them, all but one indicate a positive relationship. Thus they should be interpreted somewhat as follows: the higher the score an individual

TABLE 2.—CORRELATIONS BETWEEN PROPOSED EQUATING FACTORS AND AVERAGE SIGMA CRITERION SCORE

Equating Factor	Correlation	
Minnesota Paper Form Board.....	+.022	±.158
Wonderlic Personnel Test.....	-.093	±.156
Purdue Industrial Training Classification.....	-.349	±.139
Motor Ability.....	+.409	±.132
Purdue Test for Machinists and Machine Operators.....	-.199	±.152
Age.....	-.046	±.158
Years of Education.....	-.069	±.157

makes on the Classification test, for example, the lower his aver-

¹ Hull, Clark L., *Aptitude Testing*, p. 68, Yonkers, N.Y.: World Book Co., 1928.

age time per successful trial on any given job is likely to be. The negative signs on correlation coefficients for all but motor ability are interpreted in this manner. Since in the case of motor ability a low score indicates greater ability than a high score, the positive correlation with the time score indicates a positive relationship. The correlation between the Minnesota score and the time criterion score indicates a slight negative relationship.

The time criterion against which these initial test scores were correlated was obtained by computing sigma score equivalents for the time scores on each of the twelve jobs required of the trainees. Each trainee's array of sigma scores was averaged. This average was used in correlating with the initial measures. This procedure is justified on the assumption that these averages would be a more reliable measure of an individual's speed and accuracy in lathe work than his time score on any single job.

Age, years of education, and scores on the Minnesota and Personnel tests were eliminated as factors for use in equating groups for comparisons of time required on the twelve lathe jobs. Since none of their correlation coefficients were as high as .10, it was felt that their relatively small value in predicting the time scores as computed in this research did not justify the effort required to consider them in equating groups for the time score comparisons. However, as will be seen later, they were used in equating groups for the purposes of comparing their information gain.

Not all trainees completed all jobs successfully. It was necessary to equate groups separately for each of the twelve jobs on which the groups were compared in terms of time scores. Table 3 shows the means and standard deviations of the groups compared on each job. Also shown in Table 3 are the means and standard deviations for the groups compared in terms of average sigma scores on all jobs completed.

It will be noted that only seven of the thirty-nine comparisons favor the experimental group. On every comparison the control group had a higher mean mathematics score than did the experimental group. On eleven of the thirteen comparisons they had a higher mean motor ability score than the experimental group. It will be remembered that of all the equating factors considered, mathematics and motor ability correlated most highly with the time criterion. Thus it can be said with some assurance that

any differences found in favor of the film group are not likely due to superior initial status.

Factors considered in equating groups for purposes of comparing informational gain are shown in Table 4. The film group included forty-three cases; the non-film group had higher mean scores on three of the four equating factors. The one difference favoring the experimental group, that of mean technical information score, involves less than half a raw score point.

TABLE 3.—EQUATING OF GROUPS FOR TIME COMPARISONS

	Classification Test		Technical Information Test		Motor Ability Test		Number	
	Film	Non-Film	Film	Non-Film	Film	Non-Film	Film	Non-Film
L-1 Mean.....	11.032	11.977	16.712	16.636	.513	.573	47	44
SD.....	6.565	7.077	14.877	12.999	.904	1.019		
2-L Mean.....	10.725	12.368	16.050	18.132	.585	.612	40	38
SD.....	6.635	6.940	15.060	12.830	.839	.991		
3-L Mean.....	10.793	12.378	16.256	17.072	.666	.666	41	41
SD.....	6.579	7.034	14.666	13.238	.822	.939		
1-H Mean.....	11.157	12.757	17.586	17.334	.626	.632	35	35
SD.....	6.454	7.319	15.060	13.752	.823	1.019		
4-H Mean.....	11.878	12.526	18.068	17.660	.614	.589	37	38
SD.....	6.427	7.220	15.838	13.452	.802	.951		
5-H Mean.....	11.246	13.045	17.628	17.590	.593	.616	39	33
SD.....	6.351	7.345	15.006	14.220	.845	1.061		
6-H Mean.....	11.263	12.306	17.394	17.778	.585	.589	38	36
SD.....	6.507	7.098	14.794	13.550	.848	1.036		
7-H Mean.....	10.962	13.569	17.012	18.638	.598	.735	39	29
SD.....	6.531	7.012	14.710	14.422	.848	.957		
1-V Mean.....	11.044	12.419	17.166	17.744	.658	.581	36	37
SD.....	6.745	7.158	15.142	13.480	.820	.976		
2a-V Mean.....	10.671	12.726	16.100	16.048	.502	.500	35	31
SD.....	6.381	7.088	13.230	12.788	.828	1.035		
2b-V Mean.....	11.068	13.083	15.472	17.556	.571	.578	37	36
SD.....	6.664	6.796	15.542	13.560	.774	1.051		
3-V Mean.....	10.412	14.100	15.326	18.400	.471	.960	34	20
SD.....	6.298	7.456	12.954	13.228	.809	.986		
Average sigma score								
Mean.....	11.603	12.425	17.526	17.350	.656	.700	39	40
SD.....	6.188	7.198	15.365	13.318	.824	1.030		

TABLE 4.—EQUALITY OF GROUPS FOR COMPARISON ON INFORMATIONAL GAIN

Equating Factor Test Scores	Non-Film Group		Film Group	
	Mean	SD	Mean	SD
Minnesota Paper Form Board	37.198	8.953	35.228	9.228
Wonderlic Personnel Test	19.953	5.111	19.000	5.854
Purdue Classification Test	11.686	7.129	11.000	6.528
Purdue Test for Machinists and Machine Operators	16.872	13.056	17.364	15.412

SUMMARY

The experiment involved seven small groups of engine lathe trainees from Amertorp Naval Ordnance Plant. U. S. Office of Education training films for lathe workers were made an integral part of the instruction of one half of the trainees. The other half were taught with the conventional lecture-demonstration method. The groups were equated on the basis of tests of motor ability, mathematical proficiency, and technical knowledge for purposes of comparing the time they required per successful trial on each of twelve jobs that constituted their curriculum for skill development. For the purpose of comparing the groups in terms of their gain in technical information the factors used in equating groups were scores on tests of technical information, mathematical proficiency, perceptual ability, and general intelligence.

The Technique of Film Use.—As it is stated, the main hypothesis to be tested in the present research suggests that motion pictures are to be evaluated in terms of their effectiveness in saving time in the process of skill development. In a very real sense, however, neither films nor any other curriculum material can be evaluated apart from the methods by which they are utilized. Motion pictures are not used in a vacuum. Any evaluation of a motion picture or series of them is equally an evaluation of a method of film utilization. Consequently, the technique of film use employed in this research will be described in some detail.

The specific methods of utilization of films varied from time to time in response to the many changing factors that appear in dealing with human beings. It is probably safe to say that no two film showings were exactly the same. There were, however, a number of general principles of film use that were followed throughout the experiment.

Timing.—Ideally, film lessons should be timed to come at the point in the student's progress at which they will be most helpful. Consequently, an effort was made to have a film on any given lathe operation just before the trainees were ready to start practicing that operation. Conversely, the class was never kept waiting for a film lesson when the members were ready to start applying it.

Naturally, there was a tendency for the film lessons to be timed less well for the very fastest or the slowest workers. The average, of course, set the learning pace. However, this difficulty could not occur at the beginning of a training period, and the fact that the six-week course was divided into three intervals prevented any serious difficulty in timing film lessons to suit the needs of all students.

The emphasis placed upon proper timing of film lessons may seem to belabor the obvious. It should be noted, however, that there is strong temptation in the field of visual instruction to follow the administratively more convenient plan of lumping large units of film lessons together. All too often 'visual education' is accomplished by gathering together two or three hours' worth of training films and showing them to all trainees regardless of what machines they are operating and how much experience they have had. In the present research no film showing lasted more than twenty-five minutes.

Integration.—It has been stated previously that films used in this experiment formed an integral part of the training course. Usually the instructor demonstrated or described the next job to be done before the film was shown. After the film lesson the class was helped to make the connection between what was shown in the film and what was to be done in class. When the lathes used in the film were different from those available to the trainees, differences and similarities were pointed out.

Projects required of the students were similar to those turned out in the film demonstration, but were sufficiently different to

encourage transfer of knowledge to the performance of new tasks. Where alternative methods were demonstrated in the films the relative merits of each were discussed, and the students were helped to select the one best suited to themselves and the equipment which they were learning to operate.

When students required individual help in turning out their projects, the instructors habitually referred to the films as well as to any other previous teaching. In a very real sense, then, the film was made a part of instruction; it was never by word or action relegated to the status of a frill or an easily dispensed with supplementary device.

The Film Presentation.—Preceding each film lesson an attempt was made to motivate learning, to direct attention to important things to look for in the film, and to do any pre-teaching that might be considered essential to understanding the film.

These things were accomplished by pointing out the application of the skill to industry, by describing the job that the student was to do next, and by pointing out the various steps required in turning it out. The students were then shown the film for the first time without interruption.

When the film was over, the students filled out a self-testing exercise of short answer questions which was a part of a commercially prepared study guide.¹ A discussion followed during which the important parts of the film were reviewed, misconceptions were brought to light and corrected, and the self-testing exercises were checked.

There followed a second showing of the film. During this showing the film was stopped when necessary to bring out certain important points. A brief summary followed the final showing. As has been stated, upon returning to their shop the trainees were given further help in making the transfer from the film to their own work.

Mechanical Aspects.—All film lessons were conducted in a classroom rather than in the individual shops. The classroom was kept well ventilated and at the proper temperature as far as it was possible to do so. Since all the training took place after 10:30 P.M., there was no difficulty in darkening the room ade-

¹ *Visual Learning Guides*, Nos. 1-10 and 44-45. Chicago: The National Audio Visual Council, Inc., 1942.

quately. An effort was made to have the projection equipment set up and the film threaded before the class arrived. The experimenter took charge of the mechanical details of the lesson so that the instructor could give his complete attention to his class. Only on rare occasions were classes combined. In such cases one instructor was given direct responsibility for conducting the lesson.

A spare projection lamp and a spare fuse were carried with the machine at all times to avoid delays due to the failure of equipment. To minimize distraction the projector was placed well behind the audience. The speaker was placed on a chair directly in front of and below the screen. Every effort was made to avoid interruptions during the film showings.

Administrative Aspects of Film Use.—Two services of an administrative nature were supplied by the investigator in an effort to assure the maintenance of such standards of film utilization as were described earlier. The first was that of making films and projection equipment conveniently available for the training program; the second was that of guiding the instructors in the application of the principles of film teaching described in the foregoing paragraphs. Both were considered essential to the valid testing of the film method.

Time Comparisons.—In order to facilitate statistical comparisons, the data gathered on each of the four experimental groups were combined to make a single experimental group. The four control groups also were combined into a single group. This procedure, although perhaps somewhat unusual, was necessary because of the small numbers of cases in the subgroups. The numbers in some comparisons would have been as low as five had the subgroups been treated separately.

Table 5 shows the differences in mean time required per successful trial on each of the twelve projects that constituted the practice work on the lathe. It will be seen that in every case the film group required less time, on the average, to complete their jobs satisfactorily than did the non-film group. Ten of the twelve differences in average time spent per successful trial on single lathe jobs are more than twice their critical ratios. The largest odds that any of these differences are due to chance are found in Job 2a-V where the chances are two in one hundred. The critical ratio of the difference in average sigma score is 6.55,

which is far above that which is ordinarily required for statistical significance.

TABLE 5.—COMPARISON OF FILM AND NON-FILM GROUPS IN MEAN NUMBER OF MINUTES REQUIRED PER SUCCESSFUL TRIAL AND AVERAGE NUMBER OF REJECTIONS ON TWELVE LATHE JOBS

Job	Mean		Differ- ence	Critic- al Ratio	Rejec- tions		N	
	Non- Film	Mean Film			Non- Film	Rejec- tions Film	Non- Film	N Film
1-L	163.140	121.160	41.98	1.86	2.068	2.319	44	47
2-L	199.76	145.75	54.01	2.57	.636	.625	38	40
3-L	361.329	264.257	97.072	2.74	1.569	1.732	41	41
1-H	548.57	359.070	189.50	2.51	2.257	1.914	35	35
4-H	296.87	145.04	151.83	3.94	1.632	1.000	38	37
5-H	159.660	109.120	50.54	2.57	1.303	.436	33	39
6-H	341.44	265.03	76.41	3.66	.100	.0789	36	38
7-H	410.362	320.142	90.22	3.44	.488	.000	29	39
1-V	192.880	128.667	64.21	4.12	.000	.000	37	36
2a-V	330.952	236.786	94.17	4.25	.205	.0789	31	35
2b-V	275.611	223.689	51.992	2.33	.0769	.0513	36	37
3-V	77.50	63.32	14.18	1.12	1.200	1.147	20	34
Average								
Sigma								
Score	.333	-.433	.766	6.55			40	39

It is apparent from Table 5 that the superiority of the film group in time scores was not gained at the expense of accuracy. In only two of the twelve jobs did the film group have a greater average number of rejections than the non-film group. These jobs, 1-L and 3-L, were both done in the beginners' room. One might expect smaller differences between the film and non-film groups at a time when they had been taught by different methods for so short a period as two weeks.

It seems logical to interpret these results as meaning that sound motion pictures can, when used in the manner followed in this experiment, result in saving time in the development of skills on the engine lathe.

An examination of the distributions of time spent per successful trial reveals a tendency for a higher percentage of cases in the film group to appear in the lower time intervals and a higher percentage of the non-film cases to appear in the higher time intervals. For example, about seventeen per cent of the film

group required less than an hour per successful trial on Job 1-L as compared with about seven per cent in the non-film group. The aforementioned facts suggest a possible explanation for the economy of time resulting from the film method; namely, that the use of films reduced the period of trial-and-error activity typical of motor learning. In other words, the greater number of individuals in the film group approached their maximum efficiency more closely during the instructional period.

From the data presented in the preceding paragraphs one might be led to wonder whether or not the film teaching method resulted in greater homogeneity in the film group. Unfortunately, the experimental data do not furnish conclusive grounds for answering this question, although they do tend to indicate an affirmative answer. Table 6 shows differences in homogeneity between film and non-film groups in terms of standard deviations on each of the twelve lathe jobs.

TABLE 6.—DIFFERENCES IN VARIABILITY OF FILM AND NON-FILM GROUPS ON TWELVE LATHE JOBS

Job	SD		Differ- ences	Critic- al Ratio	Num- ber	Num- ber
	Non-Film	Film			Non- Film	Film
1-L	128.990	78.450	50.540	3.15	44	47
2-L	132.123	69.303	63.815	3.76	38	40
3-L	183.136	136.516	46.620	1.83	41	41
1-H	302.392	322.347	-19.955	.38	35	35
4-H	101.334	53.390	48.144	3.65	38	37
5-H	217.974	93.402	124.572	4.32	33	39
6-H	97.918	80.067	17.851	1.21	36	38
7-H	115.983	93.693	22.290	1.20	29	39
1-V	81.390	47.925	33.465	3.07	37	36
2a-V	105.877	63.319	42.558	2.76	31	35
2b-V	98.680	91.308	7.372	.47	36	37
3-V	51.000	31.343	19.657	2.21	20	34

The film group proved more homogeneous on all but one of these comparisons. Five of the differences were statistically significant since they were more than three times their standard error. Two others were more than twice their standard error. However, it will be recalled that the film group was also more

homogeneous with respect to initial status on two of the three tests used for equating groups. Only in technical information did the non-film group exhibit less variability than the film group. Since the groups were equated they cannot be considered random samples to start with, and there is, therefore, no way of determining the significance of initial differences in homogeneity.

If time scores on all jobs could be averaged together, would greater differences in favor of the film group become apparent? In order to answer this question the average times per successful trial of each trainee in both groups were combined in a single distribution for each job. On the basis of these combined film and non-film group distributions, sigma score equivalents were derived for each time score. Each individual's array of sigma scores were then averaged, and the film and non-film groups were compared in terms of these average sigma scores. The mean of the film group was exceeded by the mean of the non-film group by .766, indicating that the film group took less time per successful trial on the average of all twelve jobs when each job was given equal weight. The critical ratio of this difference, 6.55, was larger than that of the difference in means of any single job.

It will be noted in Table 5 that in general the critical ratios of differences were greater for the lathe jobs that were performed in the latter half of the training period. These jobs, in the opinion of the instructors, were the most difficult, and actually did allow the smaller tolerances. Furthermore, the differences in number of rejections favored the film group more in the latter jobs. It seems evident that: (a) the effect of the film method was cumulative and/or (b) the film method works best when the more complicated and more exacting operations are being taught.

Two questions of practical importance arise from the data showing that those taught with films learned their lathe skills in a shorter time than those not so taught. The first is—did not the time spent in showing films make up for any time saved from practicing on the machines? The answer is that the film lessons, lasting as they did from fifty to one hundred minutes, prolonged somewhat that instructional period that came before the trainees began actual work on the lathe. This was in spite of the fact that instructor demonstrations to the non-film groups usually had to be longer and more numerous than those given to the film groups. However the fact that most of the jobs required

two or more trials and that the comparisons between means are in terms of average time per successful trial suggests that the actual time saving due to films was greater than the differences between the means would indicate. Thus the saving of approximately forty-two minutes per trial on Job 1-L, which required four trials, amounts to a saving of one hundred sixty-eight minutes, or more than twice the time usually used in the film lesson on that job. Furthermore, three of the seven lathe films demonstrated more than one job. Finally, it should be obvious that even the straight substitution of film lessons for a part of the time on the machines would have the advantage of making it possible for more people to use the same machine.

A second question is what did the film groups do with the time they saved? Several answers to this question were observed in conducting the experiment. Some students used their spare time to do supplemental exercises on the lathe. Some made such useful shop equipment as plug gages, boring bars, and so on. Other students did extra work on blueprint reading and shop mathematics. A few assisted the instructors in record keeping and in giving individual help to slower students. Several were put on production at the Plant during or before their last week of training. This latter plan seemed sensible in view of the need for skilled workers. A suggested method of arranging film instruction to encourage such progress according to ability has been discussed by the writer elsewhere.

Why was the motion picture able to produce such marked results in the economy of time in learning lathe operations? A number of logical explanations will suggest themselves to anyone who has used films in teaching motor skills. In the first place, film demonstrations, although they cannot entirely supplant classroom demonstrations by the instructor, do have a number of distinct advantages over them. In a shop or classroom demonstration there are always those who, being on the outer fringe of the group, can see and hear little of what is going on. All trainees can see the film equally well. By manipulating lighting and the camera's position in relation to what is being shown it is possible to make the film emphasize or play down various elements of any demonstration. Furthermore, in the dark projection room by far the most dominant stimuli for attracting attention are the bright image on the screen and the clear voice

of the commentator. In the classroom or shop there are almost always distractions to compete with the instructor for the group attention. Even the noise of the machine that is being demonstrated can be cut out in the film, but in real life it may drown out many of the instructor's explanatory remarks.

Several techniques peculiar to the motion picture medium give the film added advantage over the instructor in demonstrating shop skills. The film can show minute objects greatly enlarged. For example, the action of the finishing tool was demonstrated in one film. Motions may be speeded up or slowed down as they were in the film demonstrating the sequence of operations involved in threading. Non-essential and time consuming elements can easily be omitted in the film presentation without disturbing the sequence and continuity demanded in the completion of the operation. Diagrams and animations can show machinery and processes that are difficult to demonstrate in the absence of such techniques.

There may be a temptation for instructors, especially those with little experience or those who do not particularly like their work, to omit or slide over all or parts of demonstrations for all or parts of classes. The motion picture, on the other hand, usually represents the best organized and most complete presentation of a technique that can be developed. It never gets tired or bored; it is always ready to be used if it is administered and cared for properly. In the U. S. Office of Education films the worker nearly always was shown just how the skills he was being asked to learn related to the war effort and to industry. He was made to feel that he would soon be helping to produce airplanes, jeeps, or tanks, and so on. It is difficult for the instructor, especially if he is not particularly verbal, to attach an equally strong emotional appeal to the work he is demonstrating.

It would be a serious error to infer that the motion picture can ever take the place of the instructor. The film does have qualities within its scope of usefulness that the instructor alone cannot match, but to take the maximum advantages of these qualities in a total training situation requires the active participation of an ambitious and resourceful instructor.

Comparisons of Informational Gain.—In addition to comparing film and non-film groups on the basis of their speed in developing lathe skills, comparisons were made of the two groups in terms of

the information gained during their training course. The mean technical information gain of the film group as determined by entering and leaving scores on the Purdue Test for Machinists and Machine Operators was 38.136. The corresponding gain for the non-film group was 19.034. This difference is 6.61 times its standard error, and is therefore statistically significant. The fact that the average difference between pre-test and end-test score in the film group was slightly more than twice that of the non-film group is rather striking. It is consistent in trend, however, with the findings of Arnspiger, Rulon, and a number of other investigators.

Implications of the Data for the Selection of Trainees.—Insofar as employers of machine operators accept the speed and accuracy criterion of success in machine operations, the data gathered in the present research may have some bearing on how to select employees for industrial training. The lowest correlations were obtained between the average sigma score and age, education, and measures of general intelligence and perceptual ability. This fact suggests the advisability of reexamining these commonly used criteria for the selection of prospective machine operators. Age, education, general intelligence, and so on may be valuable as indices of certain desirable qualities which are ignored in the speed and accuracy criterion employed in this research. It would, therefore, be unwise to interpret this study as completely invalidating such measures for the selection of employees for machine work.

The three factors offering the highest correlations with the time criterion were motor ability, mathematical skill, and technical knowledge. The multiple correlation for these three factors computed by the Doolittle¹ method was .448. Such a correlation, though not extremely high, should enable the employer to select with some certainty those likely to succeed in a machine operators' training course.

Does the amount of technical information that a worker possesses indicate how skillful he is in actually performing lathe operations? In an effort to provide a partial answer to this ques-

¹ C. C. Peters and E. C. Wykes, "Simplified Methods of Computing Regression Coefficients and Partial and Multiple Correlations," *Journal of Educational Research*, XXIII (May, 1931), 383-93.

tion the end-test scores made by individuals on the Purdue Test for Machinists and Machine Operators were correlated with their average sigma scores on the twelve lathe jobs required in the training program. For the control group the correlation was $-.084$, and for the experimental group, $-.298$. It is obvious from these correlations that many workers who cannot answer test questions about machine operations correctly can, nevertheless, operate the machines in a satisfactory manner. It would seem that too much weight should not be given the criterion of factual knowledge in the selection of experienced lathe operators.

CONCLUSIONS DRAWN FROM THE DATA

The data gathered in this study are sufficient to justify a large measure of confidence in the following conclusions regarding lathe trainees whose instruction includes the carefully integrated use of motion picture films as compared with originally equivalent groups of trainees who do not have the opportunity to learn through films:

a) They require on the average less time per successful trial on the projects they are asked to turn out on the lathe.

b) They do not sacrifice accuracy for speed in their work, for they do not on the average turn in more under-size jobs.

c) They learn significantly more factual information on lathe operation.

d) In view of (a), (b) and (c) it should be possible to shorten their training period by including motion pictures in their instruction in the manner described in this study.

The data gathered in this study justify some confidence in the following statements:

a) Insofar as their learning problems are similar to those of lathe trainees, time can be saved in the training periods of other types of machine operators through the use of motion pictures as training aids.

b) Films are even more effective in saving time in teaching the more complicated skills and those in which a greater degree of precision is required, than they are in teaching less complicated and less exacting skills.

c) A technique of film use involving careful timing and integration with other teaching; planned motivation, discussion, and evaluation in the actual film presentation; and efficient, unobtru-

sive manipulation of mechanical details is an effective method of visual teaching.

The data gathered did not bear out the subjective judgment that lathe operators trained with films would like their work better than those whose training did not include films.

Incidental findings supported by the data include:

a) The trainees rate motion pictures superior to the lecture and reading in "helpfulness in learning," but inferior to teacher demonstrations and actual work on the machines.

b) The best predictors of success in learning to perform lathe operations quickly and accurately are measures of motor ability, mathematical skill, and technical knowledge.

c) Trainees consider lathe tool grinding, aligning lathe centers without indicators, and turning tapers with the tailstock set over as their most difficult learning tasks.

SUGGESTIONS FOR FUTURE RESEARCH

The following are suggested as promising areas for fruitful and useful research on the subject of visual education in industrial training:

While the method used in the present research proved successful, there is no reason to feel that it cannot be improved. Furthermore, it required an additional man, the experimenter, in order to carry it on. To what extent can such a method be modified, made simpler and more convenient without losing its effectiveness? Such a question would be a fruitful one for research.

The present research was carried on with groups. The whole question of values and methods of film teaching in individualized training remains to be explored. The administrative arrangements suggested in the previous paragraphs seem to have some promise in promoting the effective use of films in both group and individualized training programs. However, objective data on the effectiveness of such arrangements might well be gathered.

Another problem of significance is that of the values of visual aids other than motion pictures. There probably is no question of films *versus* other visual aids and techniques apart from the specific curriculum purposes for which each is used.

However, the psychological and curriculum values peculiar to the various types of visual aids have not been demonstrated

scientifically. A related question deserving of the attention of research workers is the matter of what teaching jobs films themselves can do best. The present research offers only a hint in this connection.

What kind of concepts and skills are best taught by films, how do films influence various types of learners, and how do films influence the homogeneity of groups of learners? These are questions of practical importance that have not been adequately investigated.

To what extent can the findings of this study which concerned itself with engine lathe workers be generalized to apply to the training of operators of other machines, such as the milling machine, the planer and shaper, and so on? To what extent can the findings of a study of the use of films in the training of machine operators be generalized to other trades such as ship-building, airplane construction, automotive and airplane engine repair, and so on? These are questions which seem to the investigator to be of critical importance, and worthy of research.

If the present research were to be repeated, two changes might well be made. The first is that it might better be conducted with larger numbers of trainees. This should provide somewhat greater statistical reliability. The second change would be to require sufficiently more trials on each job so that it would be possible to get an adequate notion of the nature of the learning curve for each lathe operation. Such a procedure would perhaps make it possible to discover whether the advantages demonstrated by the film in the present research were due only to an initial acceleration of the learning curve.

If this were true, the non-film groups would eventually overtake the film groups. If, on the other hand, the effect of film teaching were cumulative, the differences favoring the film group would persist relatively without reference to the length of the training period.

